

Advancing Understanding of Resource Recovery and Environmental Impacts via Field Observatories

Jared Ciferno – Oil and Gas Technology Manager

**Unconventional Resource Development
Enhanced Recovery and Environmental Stewardship**

University of Texas

Austin, Texas

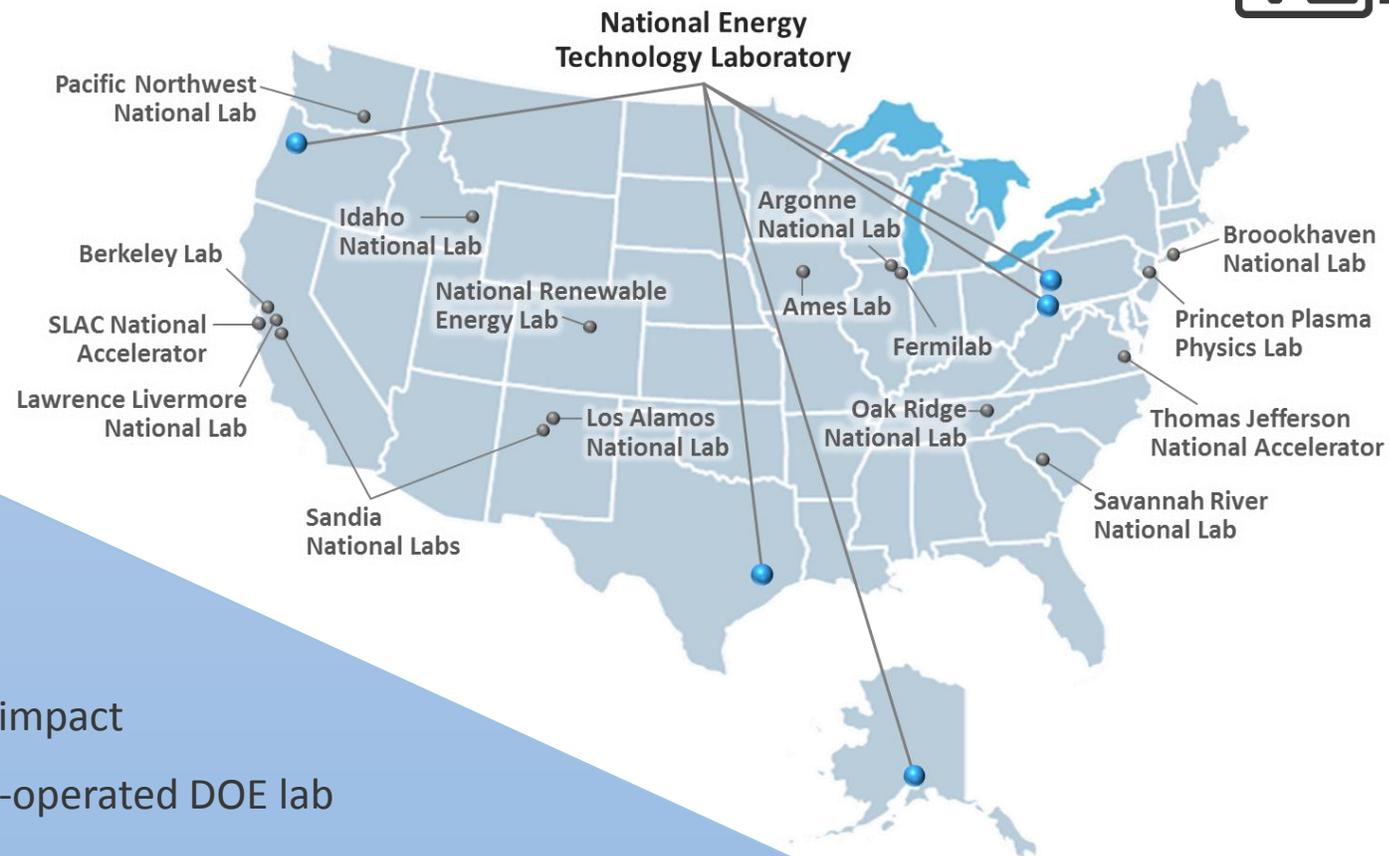
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National Energy Technology Laboratory



- Part of DOE's national laboratory system
- Five campus locations focused on fossil energy R&D
- Developing critical technology to efficiently utilize domestic fossil fuel resources with minimal environmental impact
- Only government-owned, government-operated DOE lab



NETL Oil & Gas Research Program



Unconventional Oil & Gas

Developing technologies to maximize recovery and reduce environmental impact from unconventional oil & gas development



Midstream CH₄ Quantification & Mitigation

Quantifying CH₄ emissions and developing tools and practices to mitigate emissions from natural gas transmission, distribution, and storage facilities



Offshore

Minimizing the environmental impacts of deepwater and ultra-deepwater oil and natural gas production



Methane Hydrates

Unlocking the mysteries of methane hydrates and developing ways to tap their massive energy potential

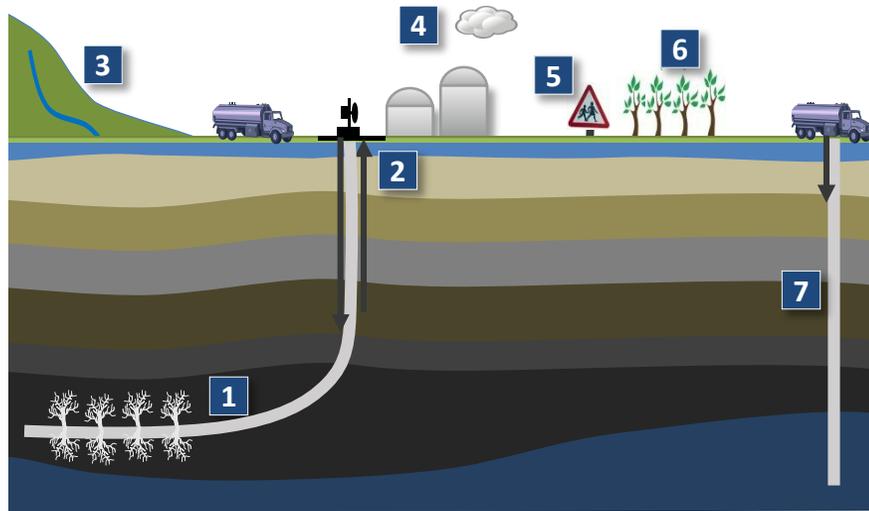


CO₂ Enhanced Oil Recovery

Investigating methods to enhance oil production using carbon dioxide (CO₂)

Unconventional Oil & Gas Priorities

Advancing technology to secure resources that cannot be produced economically through standard drilling and completion practices (e.g., shale gas, shale oil, tight gas, and tight oil)



- 1 Resource Optimization** 
- 2 Water Quality – Protect Water Resources** 
- 3 Water Availability – Prevent Water Shortages** 
- 4 Air Quality And Greenhouse Gas Emissions** 
- 5 Safeguard Human Health** 
- 6 Ecological Effects – Protect Our Natural Resources** 
- 7 Induced Seismicity – Understand And Mitigate Seismicity Risks** 



- Access abundant, domestic resources as a vital component of energy portfolio
- Enhance energy, economic, and environmental security
- Create significant income, employment, and other economic benefits.



- Understand potential impacts on human health and the environment and how they can be mitigated
- Use natural gas as a bridge fuel during transition to even cleaner energy

DOE-FE Field Observatory Initiative

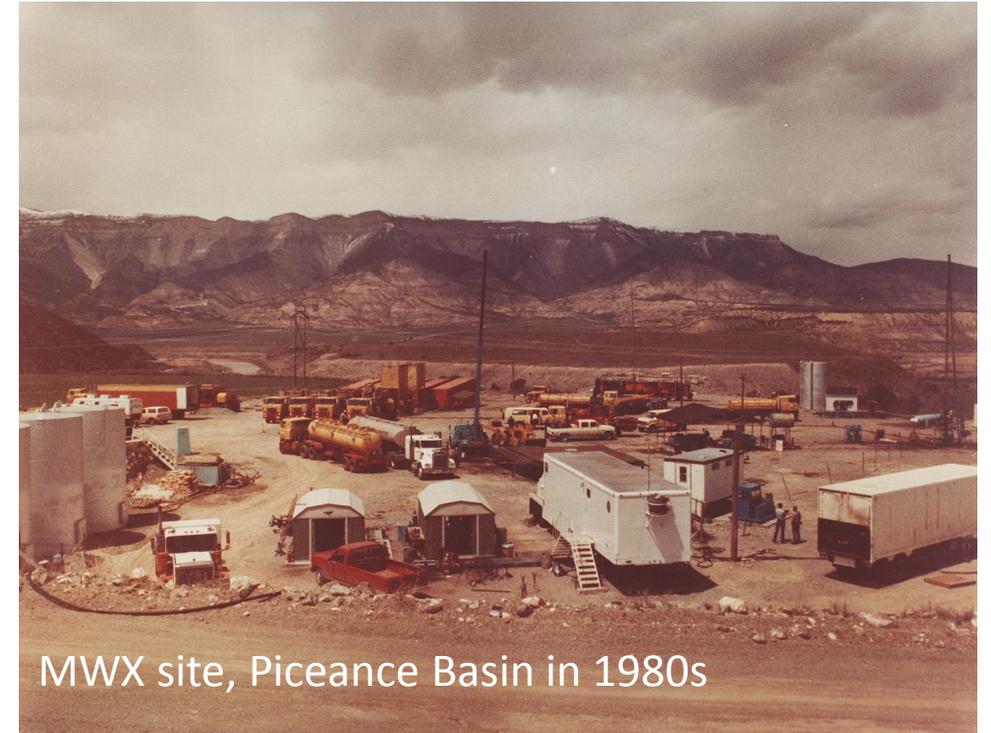
- Solicited in FY14 to advance UOG R&D objectives: *reduce development intensity and fresh water use, enhance wellbore integrity, assess air and water impacts and investigate induced seismicity*
- Long-term access to shale development sites is required for long-term, multi-disciplinary, integrated, science-based research
- Require industry partnerships to obtain site and wellbore access, but such partnerships can be hard to develop because:
- DOE cannot accept liability for risks with field projects
- Research can delay production and increase risks
- Economics of the industry hinders collaborative opportunities



Past DOE Field Observatories

Piceance Basin

- Multi-well Experiment (MWX) and M-Site project sites in the Piceance Basin where tight gas sand research was done by DOE and GRI in the 1980s
- Data and analysis provided an extraordinary view of reservoir complexities and *“... played a significant role in altering the conventional procedures, techniques, and methodology in the development of tight reservoirs.” – Paul Branagan, SPE Distinguished Lecturer**



*Branagan, P., 2009, “An Accurate Physical Model: Essential for the Economic Development of Complex Reservoirs,” SPE Distinguished Lecture Series

Past DOE Field Observatories

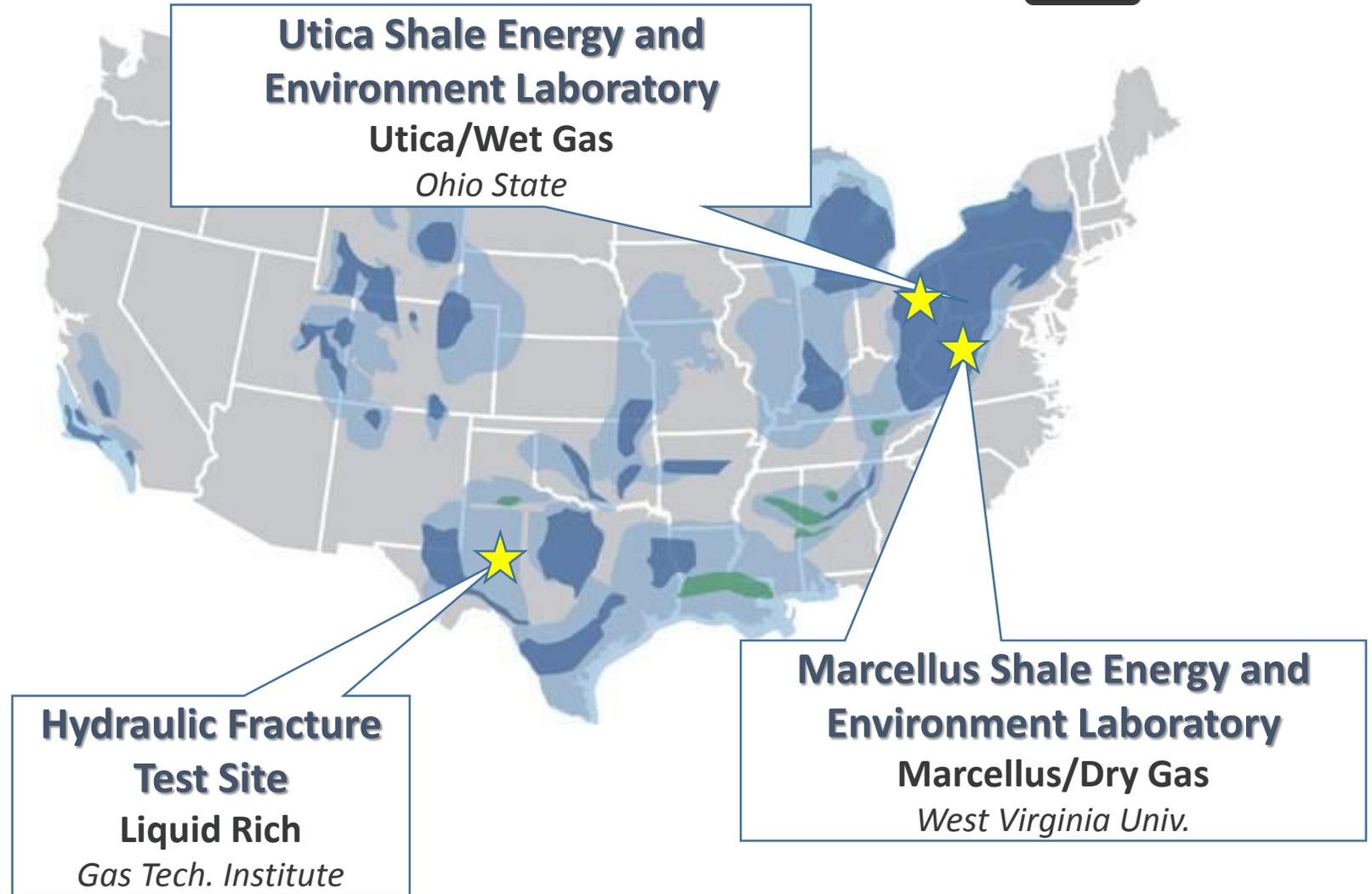
Appalachian Basin



- Multiple well experiments carried out by DOE as part of the Eastern Gas Shales Program (EGSP) in the 1970s and 1980s
- EGSP Appalachian Basin “firsts” include:
 - First nitrogen foam fracturing
 - First oriented coring
 - First high-angle shale directional wells
 - First air-drilled horizontal shale well
 - First large volume hydraulic fracturing
 - First CO₂/Sand fracturing

Three Current Field Observatories

- Dedicated science wells; instrumented production wells
- Baseline and real-time observation/monitoring
- New technology testing and demonstration
- Public and International training and outreach
- Broad collaborative opportunities



Marcellus Shale Energy and Environmental Laboratory (MSEEL)

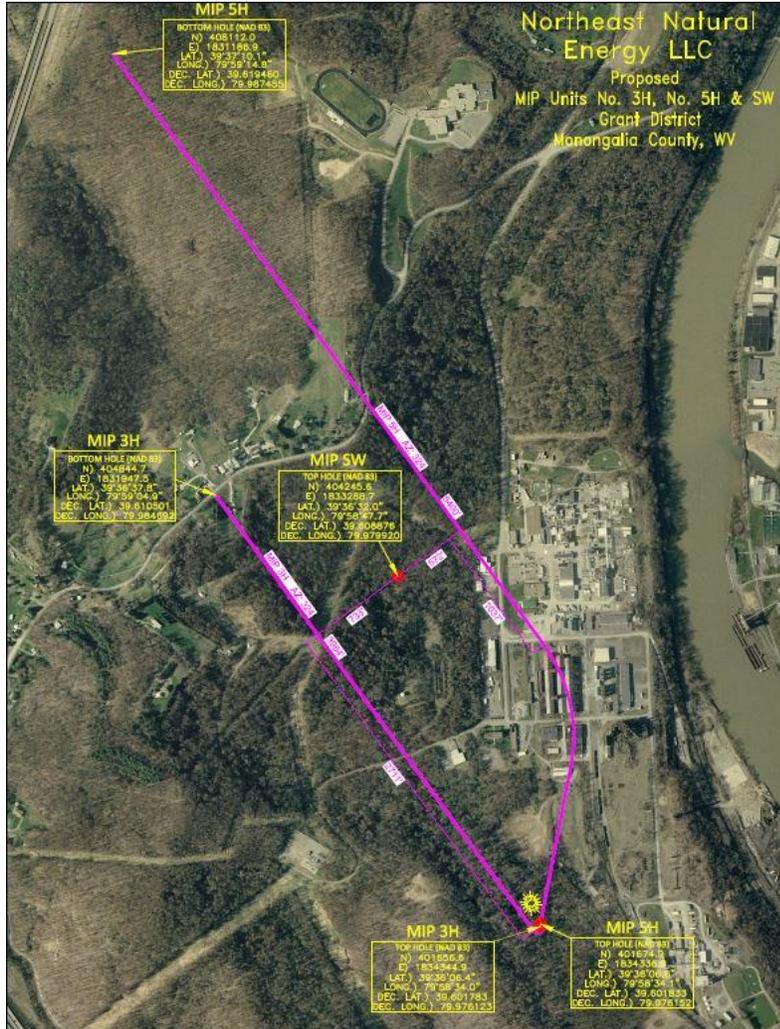


Objectives: Develop and validate new knowledge and technology to improve recovery efficiency and minimize environmental impacts of UOG development in a dry gas shale play.

Key Features of Site:

- Collaborative partners: DOE-NETL, WVU, Northeast Natural Energy (operator), Schlumberger, Ohio State.
- Well-documented baseline of production and environmental data from two previous wells drilled at location
- A dedicated vertical observation well to collect detailed subsurface data and to monitor hydraulic fracturing of project well 3H
- Multiple events over the course of the five-year project, separated by periods sufficient to analyze data

Marcellus Shale Energy and Environmental Laboratory (MSEEL)



Location of horizontal wells and science well



MSEEL Accomplishments



- NNE drilled two wells (MIP 3H & 5H) in 2015 and obtained 111 feet of 4” whole core through the Marcellus and 50+ sidewall cores in the 3H well.
- The 3H well was instrumented with fiber optic cable for distributed acoustic and temperature measurements throughout the full lateral length.
- A dedicated vertical science well, situated between the two horizontal production wells, was drilled and logged with ~150 sidewall cores obtained.
- The science well was instrumented with borehole microseismic sensors to gather data during the 3H well hydraulic fracture stimulation.
- A surface seismic array was also used to monitor the stimulation.
- Baseline noise, air and surface water data were collected before, during and after operations.

MSEEL Current Status

- Detailed core analysis underway on 4-inch vertical core and sidewall cores
- Drill cuttings are being analyzed to evaluate geochemical trends and potential leaching of trace metals during disposal
- Produced water/flowback fluids are being processed for biomass, reactive chemistry, organic acids, and noble gas and stable isotope analysis
- Produced gas samples are being analyzed for molecular composition and C/H isotope composition of methane, ethane and carbon dioxide
- Surface water analysis continues for organics (major cations/anions), inorganics, and radionuclides
- Numerical modeling is underway to investigate the influence of fluid injection rates, volume, and proppant mass on hydraulic fracture geometry
- Integration of microseismic, fracture logs, and fiber optic data to assess fluid and proppant placement under way

MSEEL Next Steps

- Maintain MSEEL web application and data portal online at mseel.org
- Continue air, surface water and production monitoring activities
- Publish results of portfolio of analyses
- Plan and execute additional data gathering and experimental activities for remainder of project period



Permian Basin Hydraulic Fracturing Test Site (HFTS)



Objectives: Advance understanding of the hydraulic fracturing process in a tight oil reservoir, enabling improved design and execution of fracture stages such that the number of infill wells and water volumes are reduced

Key Features of Site:

- Collaborative partners: DOE-NETL, GTI, Laredo Petroleum (operator), seven other producers, Halliburton, CoreLabs, University of Texas at Austin, BEG
- Location in Permian's Reagan Co. is well characterized (87 nearby wells)
- Observatory Site includes 11 horizontal wells, in Upper and Middle Wolfcamp formation (10,000 ft horizontal legs)
- Two refractured horizontal wells adjacent to pad wells
- Vertical pilot well drilled for sidewall cores, logs and injection test data
- Slant hole core well located between horizontal wells to intersect hydraulic fractures

Permian Basin Hydraulic Fracturing Test Site (HFTS)

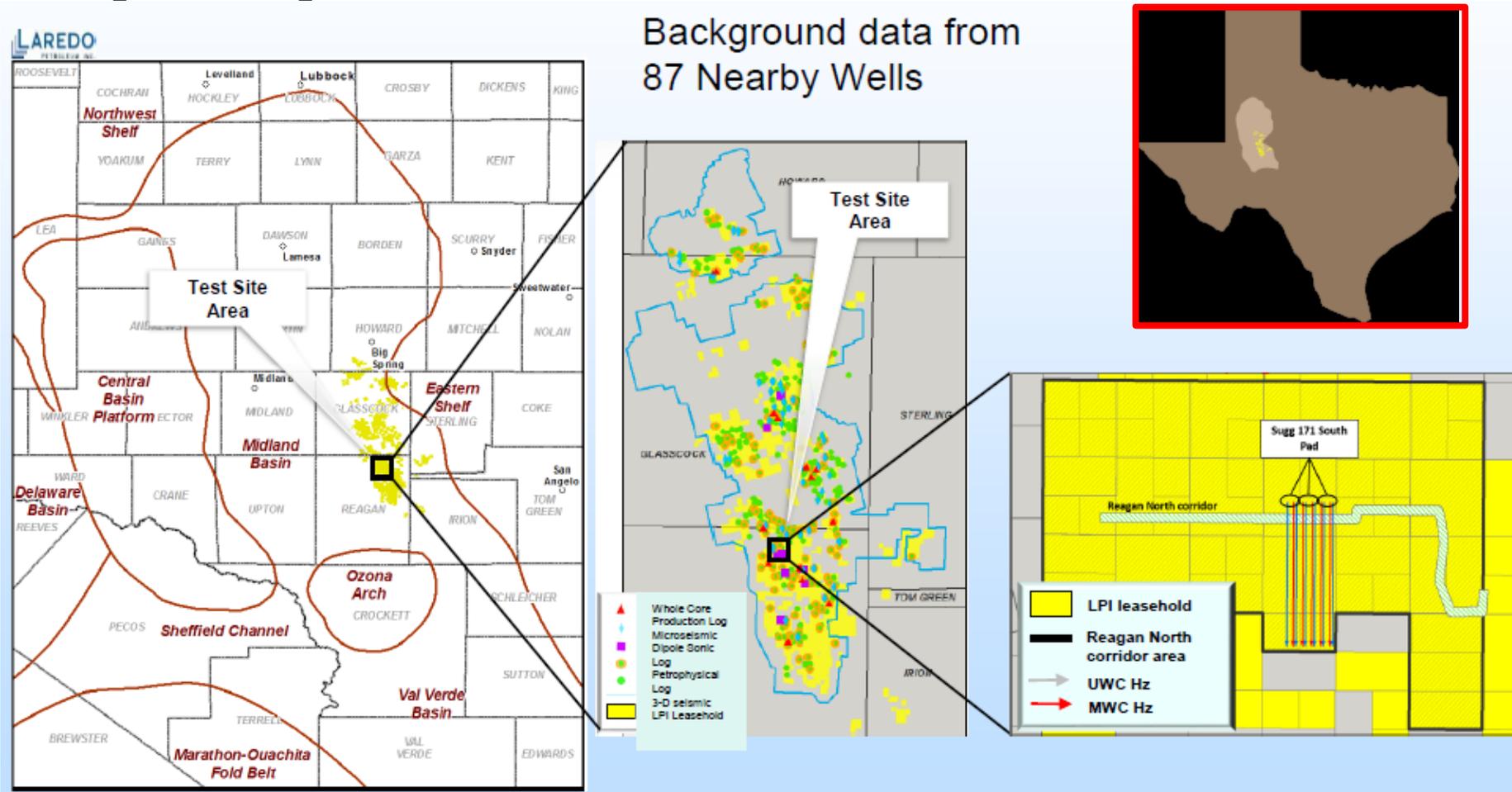
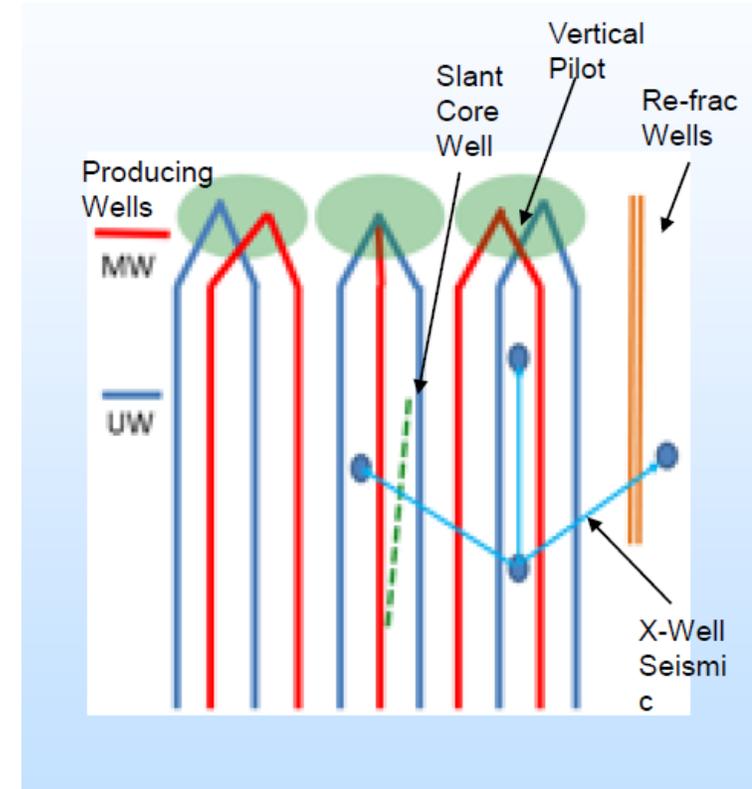
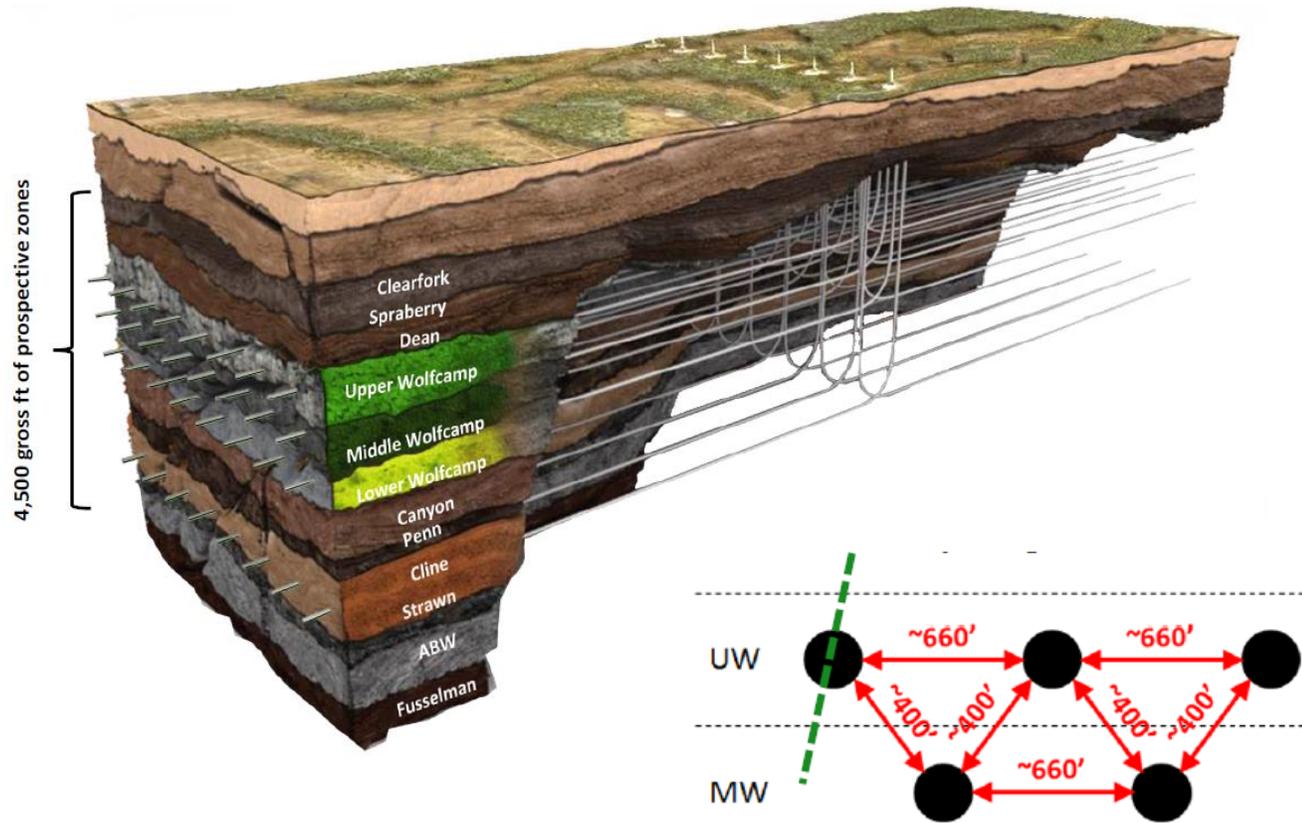
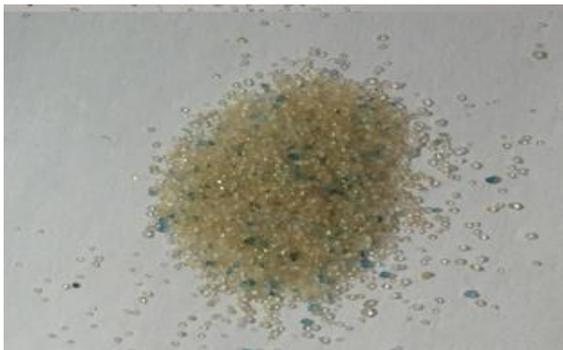
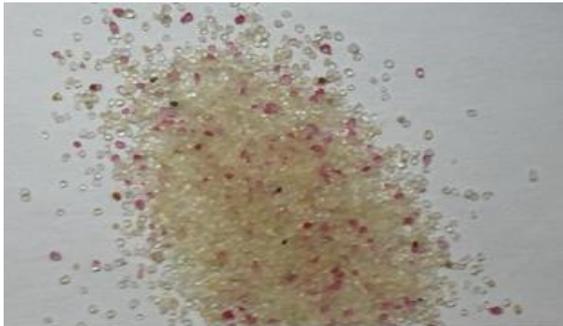


Image Courtesy: Laredo Petroleum

Permian Basin Hydraulic Fracturing Test Site (HFTS)



HFTS Accomplishments



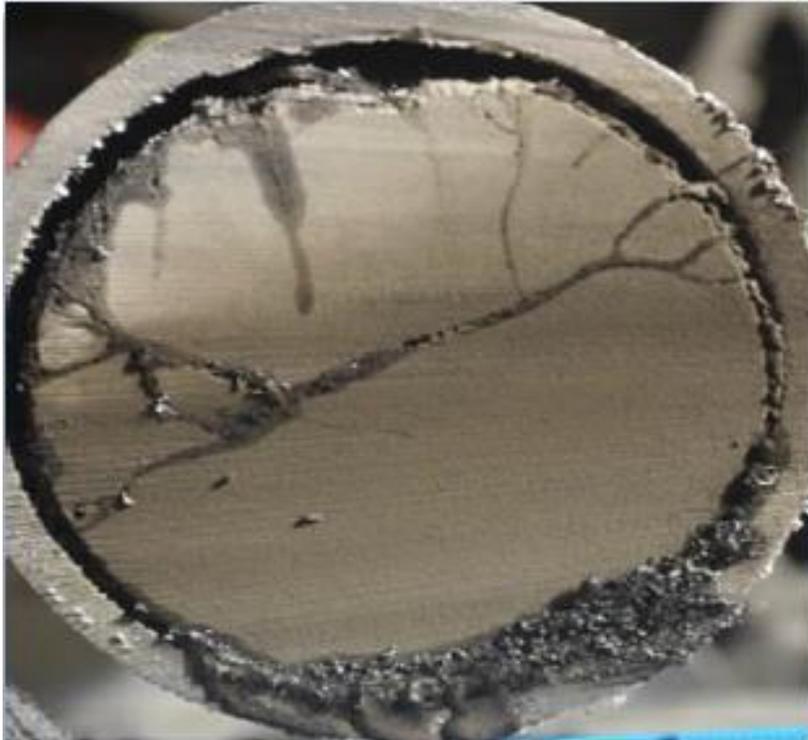
- Water, air sampling prior, during, after HF
- Cross-well seismic surveys prior and post HF
- Diagnostic fracture injection tests
- 400+ fracture stages completed in 11 wells; radioactive and chemical tracers employed, as well as colored proppant in wells close to slant core well
- Microseismic monitoring conducted during fracturing treatments
- Slant core well drilled through stimulated rock volume; 595 feet of core recovered in Wolfcamp zones
- Pressure sensors installed in slant well to monitor pressure during production

HFTS Current Status

- Website for partner data sharing being maintained and updated
www.thepermianproject.com
- Reservoir pressure monitoring underway during production
- Core characterization underway
- Water and air sampling continues during production operations
- Hydraulic fracture modeling is in progress
- PVT testing is ongoing



HFTS Next Steps



Slant well core in core barrel. This is the first time a public research well has been cored through the stimulated rock volume of a horizontal well

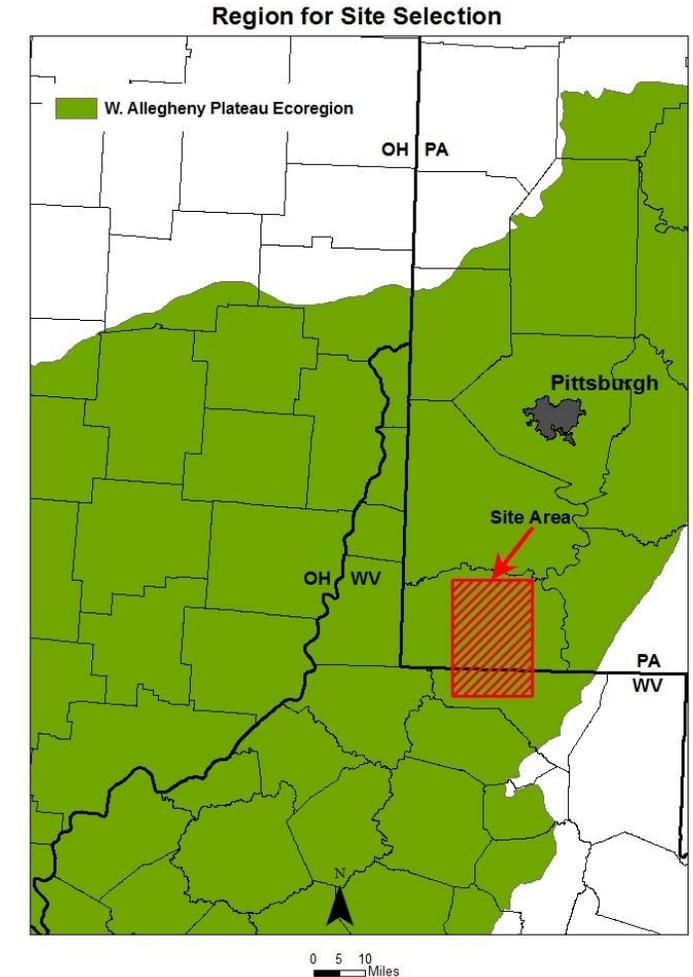
- Continue field data collection: interference testing, pressure and production monitoring, environmental sampling
- Plan and execute additional data gathering and experimental activities for remainder of project period (through end of 2016 at least)
- Publish results of analyses on:
 - Inter-well interference
 - Stimulated rock volume (SRV) & reservoir depletion over time
 - Effectiveness of geological fracture barriers
 - Effectiveness of alternative HF designs
 - Variations in performance by stage/perf cluster post stimulation

Utica Shale Field Observatory

Objectives: Develop and validate new knowledge to improve recovery and minimize impacts of UOG development

Key Features:

- Collaborative partners: DOE-NETL, Ohio State U., WVU, Ohio U., U. Calgary, CSI, GSI, HARC, Miami U. (operator still TBD)
- Deep Utica (~14,000 ft) between Pittsburgh and Morgantown
- Specifics on subsurface scientific data acquisition TBD
- Environmental long-term baseline monitoring pre/post drilling

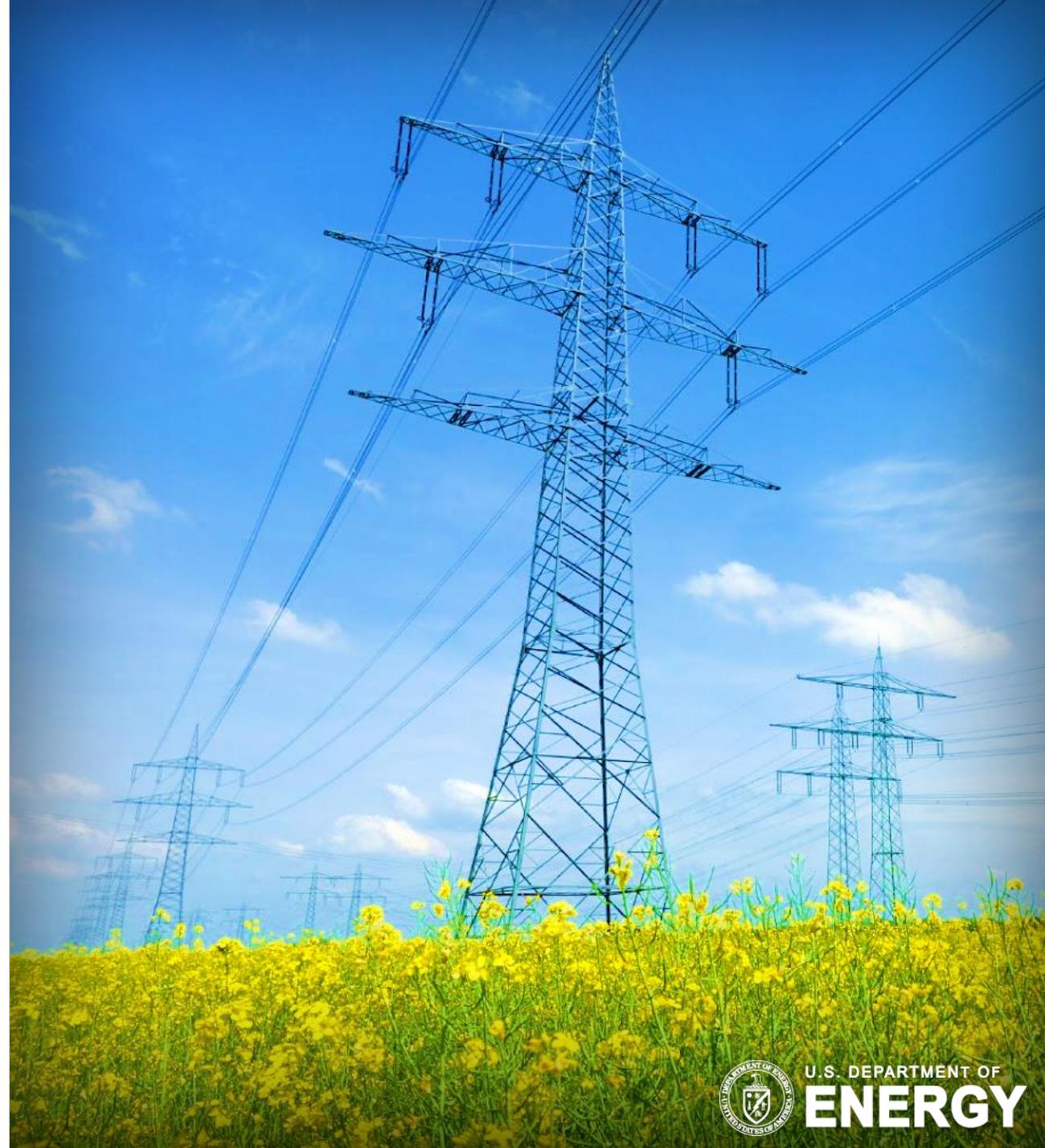


Looking Forward



- DOE is currently developing a strategy for an expanded number of observatory wells in multiple locations
- Request for Information (RFI) will seek to gather insights from industry, academic researchers and others on the research needs best served by additional observatories
 - What resource types (shale oil, shale gas, EOR, ROZs)
 - What plays or subplays?
 - What experiments or research activities?
 - How to quantify environmental impacts?

THANK YOU!



U.S. DEPARTMENT OF
ENERGY

Past DOE Field Observatories

Appalachian Basin



“The Eastern Gas Shales Program helped expand the limits of gas shale production and increased understanding of production mechanisms. A look back at the data and innovations generated by the program makes it clear that the EGSP was simply ahead of its time. It is one of the great examples of value-added work led by the DOE -- it just took 25 years before its value became clear.”

Dr. Terry Engelder - Penn State University

Solutions for Today Options for Tomorrow

For More Information, Contact NETL
www.netl.doe.gov



Field Observatory Funding Plan



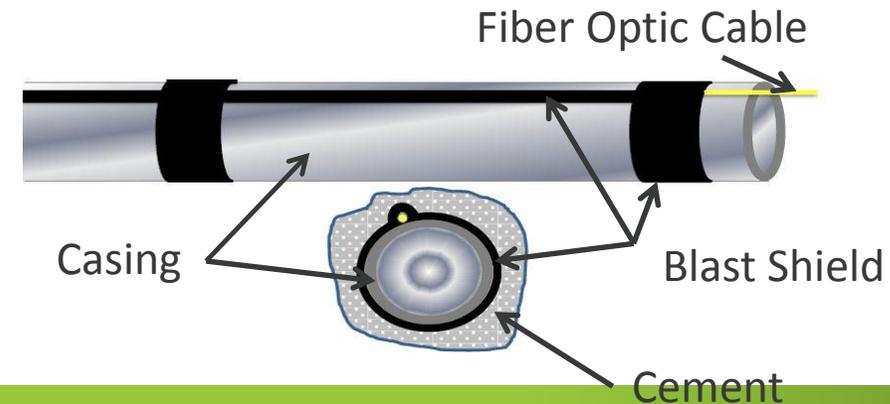
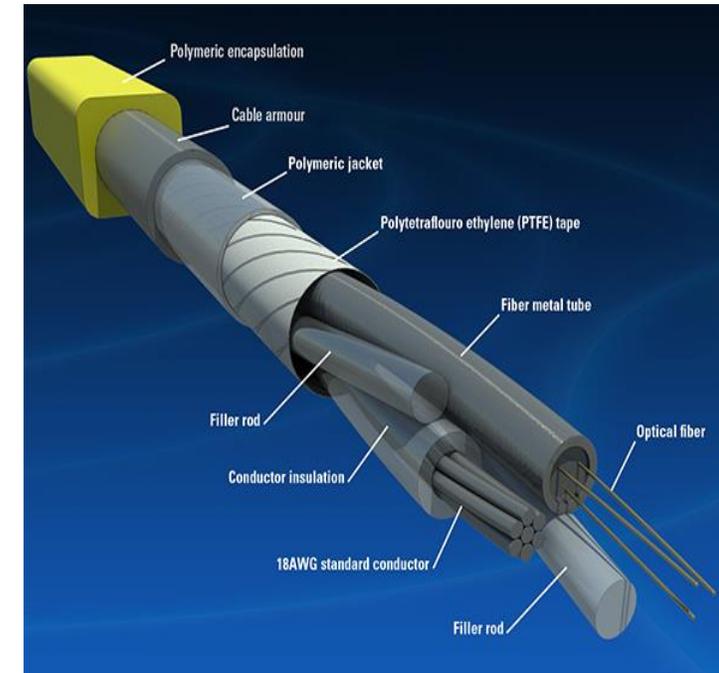
PI	FY 2014 (\$million)	FY 2015 (\$million)	FY 2016* (\$million)	FY 2017* (\$million)	FY 2018* (\$million)	FY 2019* (\$million)	TOTAL (\$million)
WVU Marcellus	0.549	5.498	1.252	0.804	0.564	0.563	9.230
GTI Permian	1.203	0.048	6.362				7.613
OSU Utica	1.167	0	1.079	3.0	1.700	0.316	7.262
TOTAL	2.919	5.546	8.693	3.804	2.264	0.879	24.105

* estimate

- **Potential Additional Sites (Research Topics)**
 - Williston Basin/Bakken (water use, surface handling, drilling intensity reduction)
 - DJ Basin/Niobrara (recovery in low-pressure settings)
 - Monterey, New Albany (improved recovery in technically challenging plays)
- **Future RFIs and FOAs solicit information and proposals for additional sites**
- **Future FOAs for additional experiments after additional sites have been added**

MSEEL Fiber Optic Monitoring

- Installation of fiber-optic cable in 3H well tied to the outside of production casing
- Data collected for analysis of fracture distribution as well as better understanding of where production is coming
- Combinable with cable protection systems that allow oriented perforation



MSEEL Microseismic Monitoring of Fracturing

